

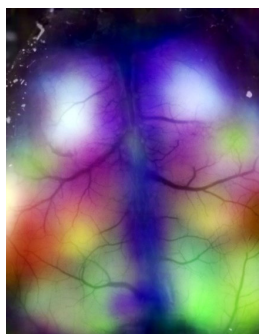
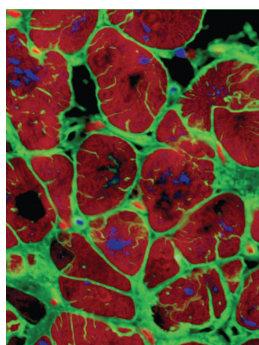
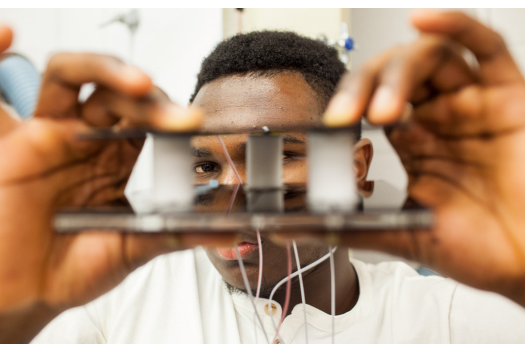
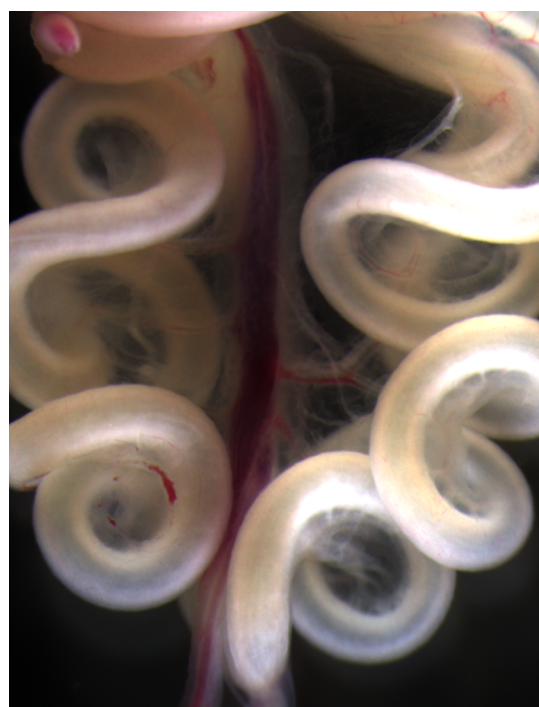
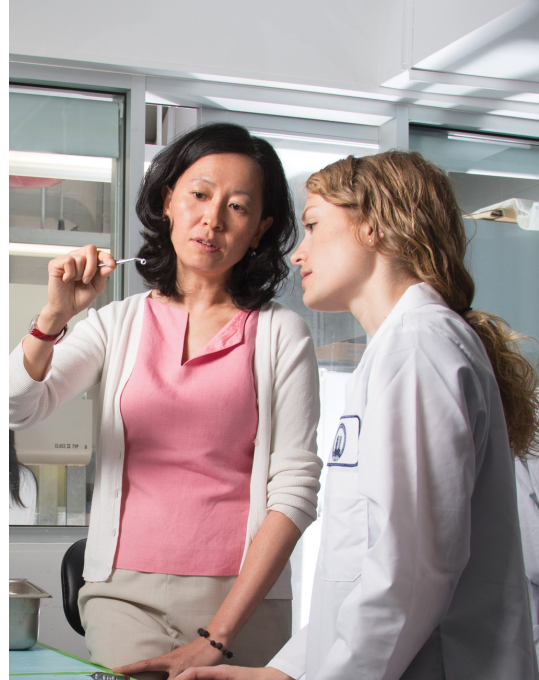
Summer/Fall 2018

# BME INSIGHTS

by



Department of Biomedical Engineering  
COLUMBIA | ENGINEERING





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## Columbia BME in Numbers



**1:4** Faculty-to-  
Undergraduate Student  
ratio



**Over \$20M** in Annual  
Faculty Research  
Expenditures 2017-2018



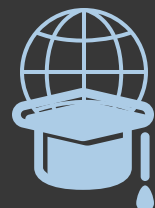
**3** Faculty Elected to the  
National Academy of  
Engineering



**90%** of BS and MS  
Students Participate in  
Research



**16** Startups Launched  
by Students and  
Faculty since 2014



**Diverse Student  
Population**



**13** AIMBE Fellows in  
Faculty



**112** Undergraduate Students  
**134** Masters Students  
**138** PhD Students

Special thanks to Mindy Farabee, Richard Kam, Jesse Adams, and Holly Evarts

Photos on cover from top, clockwise. 1) Helen Lu and a student in the lab; 2) Small intestine of the chick embryo at embryonic day 16 (courtesy of Nandan Nerurkar); 3) Class of 2018 Undergraduate BME Students; 4) Image composite showing patterns of spontaneous neural activity occurring across the bilateral cortex of an awake mouse. Colors indicate different patterns of activity over time overlaid on a steady-state grayscale image (Credit: Ying Ma and Elizabeth Hillman/Columbia's Zuckerman Institute); 5) Skyline of midtown Manhattan; 6) High school student in Hk Maker Lab Program; 7) Butler Library on Columbia University campus; 8) Adult-like human heart muscle engineered from pluripotent stem cells contains transverse tubules (Credit: Gordana Vunjak-Novakovic);





We are pleased to introduce Columbia BME Insights, Fall 2018 Edition.

The Department was officially established in 2000 by the founding chair of the Department Dr. Van C. Mow. The Department offers educational programs leading to B.S., M.S., Ph.D. degrees as well as M.D. - Ph.D. and M.S. – M.D. degrees in collaboration with the Columbia University Medical School. Currently, we have about 110 undergraduate students (juniors and seniors), 130 master students, and 140 doctoral students. Students in our biomedical engineering programs, not only excel in academics, but also flourish in translational medicine and entrepreneurship through BioMedX program led by the Department (formerly Coulter Translational Research Program). The Department of Biomedical Engineering is ranked #12 in the nation by the US News and World Report (2018).

In the past decade, our faculty, students, academic and research programs have been rising to new levels of excellence. Currently, the Department of Biomedical Engineering has 20 tenured or tenure track faculty and 2 lecturers. Our students benefit from highly productive and prominent biomedical engineering scholars in the Department. Professor Gordana Vunjak-Novakovic is one of 16 University Professors at Columbia University, the first University Professor in the history of Columbia Engineering. The Department has three faculty members elected to fellowship of the US national and the world prestigious academies, including the US National Academy of Engineering, US National Academy of Medicine, US National Academy of Innovators, Academia Sinica, the Third World Academy of Science. We also have 13 elected members of the American Institute for Medical and Biological Engineering. We have three faculty members in the Department serve as the editor-in-chief of premier journals in the field, including Biomaterials (Kam Leong), IEEE Transactions on Neural Systems and Rehabilitation Engineering (Paul Sajda), and IEEE Transactions on NanoBioscience (Henry Hess). The Department ranks at the top in terms of NIH/NSF funding per faculty in the nation.

Looking ahead, we have established our priorities in the next few years. We are enhancing and renewing our connections and collaborations with the Columbia University Medical Center (CUMC) under the leadership of Dean Mary Boyce and her vision of Engineering in Medicine. The Department will play a leading role in building this important initiative for Columbia Engineering and CUMC. In the upcoming years, we will work with our CUMC colleagues to search for faculty in areas of Bioinformatics, Single Cell Technology, Big Data/Machine Learning, and Biomechanics. We are expanding and enhancing our M.S. program in biomedical engineering and emphasizing cutting edge biomedical engineering technologies such as big data/machine learning (Data Science Institute), biomanufacturing, and organ-on-a-chip. By leveraging our local intellectual community and resources, we aim to develop one of the top go-to biomedical engineering master programs in the country. Specifically, we are working closely with the Engineering School, New York City, and our collaborating industrial leaders in developing the next generation cutting Engineering Research, Education, and Entrepreneurship hub to be located on the new Columbia University campus, Manhattanville.

With these priorities and opportunities, we hope that we will be able to challenge ourselves while providing new fertile ground to elevate Columbia's Biomedical Engineering Program to the next level of excellence. Please stay tuned and come back to check our progress in the near future.

Best regards,

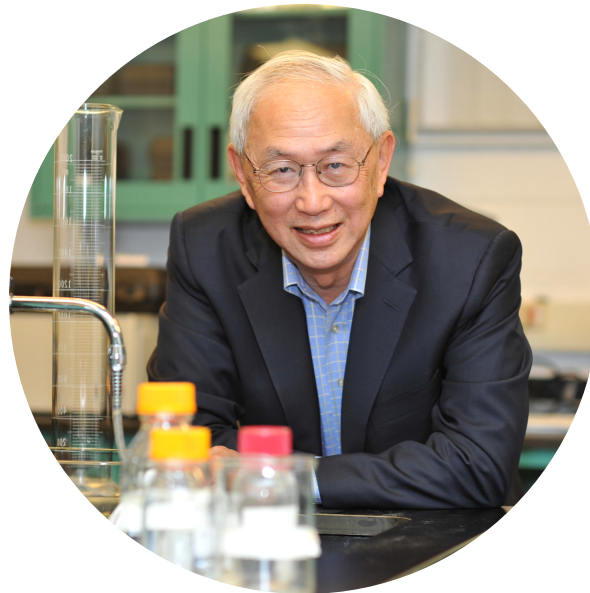
X. Edward Guo, Ph.D.  
Chair and Stanley Dicker Professor of Biomedical Engineering



# VAN C. MOW GRADUATE FELLOWSHIP

Dr. Van C. Mow is one of the earliest researchers in the field of biomechanics. Throughout his more than 50-year career, Dr. Mow has made truly outstanding and brilliant contributions to orthopaedic biomedical engineering, including biomechanics studies on articular cartilage, intervertebral disk, knee meniscus, diarthrodial joint mechanics, joint lubrication, and osteoarthritis.

Among Dr. Mow's many achievements, he was the founding chair of the Department of Biomedical Engineering at Columbia University's Fu Foundation School of Engineering and Applied Science from 2000 to 2011. To honor Dr. Mow for his many contributions to the Department of Biomedical Engineering, Dean Mary C. Boyce has created the Van C. Mow Graduate Fellowship. In addition to recognizing Dr. Mow's accomplishments, the fellowship will serve to propel the careers of future biomedical engineering researchers and teachers and strengthen the School of Engineering.



Columbia Engineering seeks additional support to grow the Van C. Mow Graduate Fellowship Fund. To add to Professor Mow's legacy and invest in doctoral education in Biomedical Engineering at Columbia, please contact Jaclyn Chu at [jac143@columbia.edu](mailto:jac143@columbia.edu) or (646)-745-8414 or donate online at [www.givenow.columbia.edu](http://www.givenow.columbia.edu).

## Fall 2018

## Biomedical Engineering Seminar

Sep 14	Nandan Nerurkar, Columbia University
Sep 21	Kaiming Ye, Binghamton University
Oct 5	Michael Miller, Johns Hopkins University
Oct 12	Steven Adie, Cornell University
Oct 19	Song Li, University of California, Los Angeles
Oct 26	Jennifer Elisseeff, Johns Hopkins University
Nov 2	Ed Munro, University of Chicago
Nov 9	Lori Setton, Washington University in St. Louis, (Van C. Mow Lecture)
Nov 16	Lihong Wang, California Institute of Technology
Nov 23	Thanksgiving Recess
Nov 30	Ovijit Chaudhuri, Stanford University
Dec 7	Zev Gartner, University of California, San Francisco



## Assistant Professor Nandan Nerurkar, Ph.D.



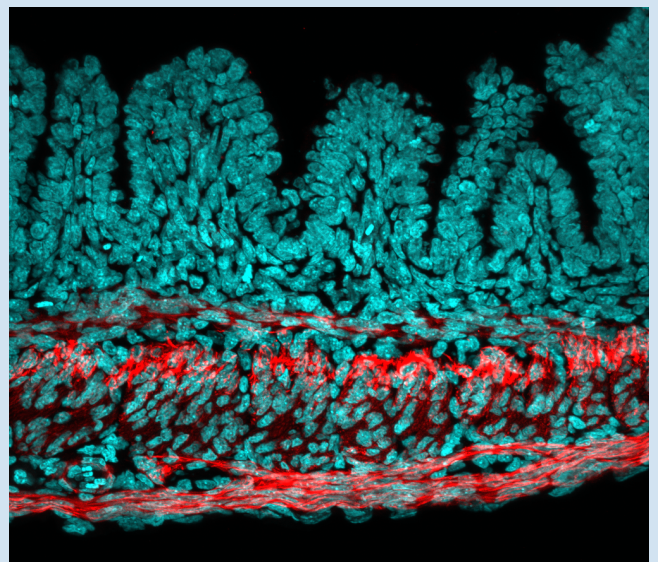
Nandan Nerurkar received his undergraduate degree in Biological Engineering from University of Maryland in College Park, then joined the lab of Larry Taber at Washington University in St. Louis as a Masters student. There, Nerurkar first became interested in the application of biomechanics as a way of studying embryonic development.

From there, Nerurkar continued on to University of Pennsylvania, where as a PhD student with Professors Robert Mauck and Dawn Elliott, he developed multiscale tissue engineering approaches for the intervertebral disc, alongside theoretical approaches to study the growth mechanics of engineered tissues, and how they compare mechanically to their native tissue counterparts. During this time, Nerurkar's interests shifted from replicating the complex architecture of the body to asking why and how that complexity is established in the first place.

Moving in this direction, Nerurkar conducted his postdoctoral training with Cliff Tabin at Harvard Medical School. A lab consisting entirely of developmental and evolutionary biologists, this was an exciting and immersive way to learn the tools necessary to study embryonic development from the standpoint of mechanobiology.

Nerurkar's research aims to understand how we are sculpted – with astonishing precision – from a seemingly disorganized ball of stem cells through embryonic development. This transformation has long been studied from a gene-centric approach, but there is growing appreciation that to truly understand embryonic development, and more importantly to engineer development, it is critical to understand not only the genes that are responsible for shaping the embryo, but how those genes encode physical processes. What are the forces that shape us? How are those forces reproducibly generated to balance growth, deformation, and cell behaviors like differentiation?

Through these studies, which encompass morphogenesis and organogenesis of the respiratory, gastrointestinal, and central nervous systems, Nerurkar's goal is to establish the design principles of embryonic tissue formation, and to repurpose them for regenerative medicine and tissue engineering applications.



Villi and muscle layers of the chick embryonic small intestine; Cell nuclei labeled in blue, and smooth muscle in red



## New Cell Therapy Aids Heart Recovery —Without Implanting Cells

Heart disease is a major global health problem—myocardial infarction annually affects more than one million people in the U.S. alone, and there is still no effective treatment. The adult human heart cannot regenerate itself after injury, and the death of cardiac muscle cells, known as cardiomyocytes, irreversibly weakens the heart and limits its ability to pump blood.

Researchers have turned their focus to stem cell transplantation for cardiomyocyte replacement and recovery of heart function, but studies have shown that implanted stem cells have difficulty surviving and differentiating into cardiomyocytes to repair the damaged muscle. When stem cells were differentiated into cardiomyocytes before implantation, heart function improved, but with a complication: the implanted cardiomyocytes did not contract synchronously with the heart, thus causing potentially lethal arrhythmias (abnormal heart rhythm).

A team of Columbia University investigators, led by Biomedical Engineering Professor Gordana Vunjak-Novakovic, has designed a creative new approach to help injured hearts regenerate by applying extracellular vesicles secreted by cardiomyocytes rather than implanting the cells. The study, published online today in *Nature Biomedical Engineering*, shows that the cardiomyocytes derived from human pluripotent stem cells (derived in turn from a small sample of blood) could be a powerful, untapped source of therapeutic microvesicles that could lead to safe and effective treatments of damaged hearts.

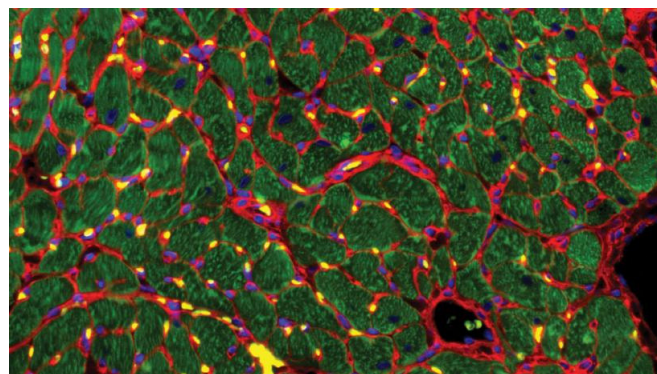
Cell-secreted microvesicles are easy to isolate and can be frozen and stored over long periods of time. Such an “off-the-shelf” product has several major advantages over cell therapy—1) it can be used immediately in an acute-care setting, unlike cells that can take months to isolate and grow; 2) it does not cause arrhythmia (which often occurs when cells are transplanted); and 3) the regulatory path towards clinical application is much simpler than for a cell-based therapy.

It is well known from numerous clinical studies that most of the implanted stem cells are washed away within hours of the treatment, but there still are beneficial effects. This has led to the informal “hit-and-run” hypothesis, meaning that the cells deliver their cargo of regulatory molecules before leaving the site of injury.

“Consistent with this hypothesis, we postulated that the benefits of cell therapy of the heart could be coming from the secreted bioactive molecules (such as micro RNAs), rather than the cells themselves,” says Vunjak-Novakovic, the study’s senior author, University Professor, The Mikati Foundation Professor at Columbia Engineering, and professor of medicine at Columbia University Vagelos College of Physicians and Surgeons.

“So we explored whether the benefits of cell therapy of the injured heart could be achieved without using the cells. This way, we would largely simplify the translation into the clinic, and avoid the burden of arrhythmia associated with implantation of contractile cells.”

Nearly all cells secrete and uptake tiny extracellular vesicles that are filled with genetic messages that can influence recipient cells. These extracellular vesicles are like letters that cells use naturally to communicate with their neighbors, both near and far, within the body.



Recovery of the injured heart muscle after 4 weeks of treatment with extracellular vesicles. Immunostains: wheat germ agglutinin (red), troponin (green) and DAPI (blue).



“We reasoned that the cardiomyocytes would be the best source of molecules driving the recovery of injured heart, as it is well known that these cells can build muscle when used in tissue-engineering models,” says Bohao Liu, the paper’s co-lead author and MD/PhD candidate in Columbia Engineering’s department of biomedical engineering. “I’m very excited about our promising results, and I believe that the cell-free therapy represents a step in the right direction for developing safe and effective treatments of the infarcted heart.”

The interdisciplinary team, which included bioengineers, clinicians, and systems biology scientists, derived cardiomyocytes from adult human stem cells and cultured these cells to allow them to secrete extracellular vesicles. The vesicles secreted by undifferentiated stem cells were used for comparison. The researchers then used next-generation sequencing to read their messages and instructions. They found that the extracellular vesicles from cardiomyocytes—but not from stem cells—contained cardiogenic and vasculogenic microRNAs that are very powerful regulatory molecules.

Building on the expertise of Vunjak-Novakovic’s lab in biomaterials and hydrogels, the team encapsulated the vesicles in a collagen-based patch that slowly released them over the course of four weeks when implanted onto the injured heart in rat models of myocardial infarction. The researchers monitored the heart to measure blood-pumping function and look for any signs of arrhythmia.

“We were really excited to find that not only did the hearts treated with cardiomyocyte extracellular vesicles experienced much fewer arrhythmias, but they also recovered cardiac function most effectively and most completely,” says Vunjak-Novakovic. “In fact, by four weeks after treatment, the hearts treated with extracellular vesicles had similar cardiac function as those that were never injured.”

The team next plans to exploring the specific mechanisms behind the therapeutic effects observed in this study.

“Once we better understand how exactly the extracellular vesicles do what they do,” Vunjak-Novakovic adds, “we should be able to extend their use to a range of cardiovascular diseases, and significantly advance the field of cell-free heart therapy.”



**Gordana  
Vunjak-  
Novakovic:**  
University  
Professor

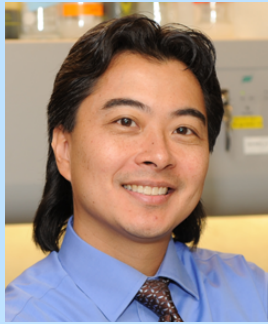
Gordana Vunjak-Novakovic, the Mikati Foundation Professor of Biomedical Engineering, professor of Medical Sciences at P&S, and director of Columbia’s Laboratory for Stem Cells and Tissue Engineering, has been appointed a University Professor, Columbia University’s highest academic honor.

Dr. Vunjak-Novakovic has been a pioneer in the engineering of functional human tissue for use in regenerative medicine. Together with her research team, she has been able to engineer cardiac tissue by culturing stem cells and to grow bone grafts for facial reconstruction surgery. Her discoveries have led to new approaches for treating injuries and complex diseases and have supported the development and evaluation of therapeutic drugs.

Dr. Vunjak-Novakovic completed her PhD in chemical engineering at the University of Belgrade and relocated to the United States after receiving a Fulbright Fellowship. She is the founder of three public-spirited biotechnology companies, the first woman engineer to deliver the Director’s Lecture at the National Institutes of Health, and the first of Columbia’s female faculty members to be elected to the National Academy of Engineering.



## Clark Hung: Saving Donated Tissue



Professor Clark Hung and former BME PhD student Eric Lima are the co-inventors and engineers of the Missouri Osteochondral Preservation System (MOPS), which has won the 2018 Best Sports Medicine Award, presented by Orthopedics This Week.

In a partnership between MTF Biologics, Missouri Orthopedic Institute and ConMed, Drs. Hung and Lima have invented a method that significantly increases storage period of donated cartilage, bone, ligament, and intervertebral disk tissue before transplantation.

Such donated tissue can be used for cartilage repair of injury caused by trauma or arthritis. Currently, the standard shelf-life of osteochondral allografts is 28 days under refrigeration, after which cell begin to lose viability and clinical outcome declines.

However, testing and clearing the donated tissue can take several weeks, leaving a short timeframe for doctors to identify and match the tissue to a recipient.

With MOPS, the viable clinical window extends to 57 days, allowing for more flexibility in the time-frame for testing and matching the donated tissue with potential recipients. Additionally, the grafts can be stored at room temperature, allowing physicians to eliminate special storage and refrigeration. These advancements have led to less waste of donated tissue and allow physicians to optimize the use for recipients.



## Katherine Reuther: Designing a Design Course

Innovative courses and educational tools are just as important in graduate instruction, says Katherine Reuther, PhD, lecturer in biomedical engineering. "While BME undergraduates receive broad, structured training in many aspects of biomedical engineering, BME graduate students come from diverse backgrounds, including research fields, industry, and educational experience in life sciences, mathematics, computer science, and several fields of engineering," says Reuther. "Many are seeking to redefine their career direction, and most master's students are seeking employment in industry after graduation."

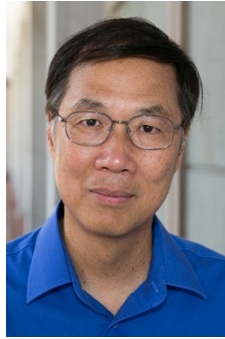
To meet those needs, Reuther is leading a course, Graduate Special Topics: Biomedical Design, to provide graduate students with real-world training in biomedical design and innovation to help prepare them for the workforce.

The course explores all elements of the design process, including identifying clinical needs, concept generation, concept selection, and implementation. Students work in teams and apply the design process to a real biomedical engineering project.

"The structure of the course incorporates a hybrid learning strategy with core lectures and collaborative learning experiences," says Reuther. "The core lectures are being delivered through a combination of short videos and visiting experts. Students practice and refine concepts presented in the lecture during in-class workshops, group exercises, case studies, design review meetings, and presentations, and through completion of a team design project."

"Our program capitalizes on the deeper and more diverse training and prior experiences of our graduate students," says Reuther. "We find that graduate students are especially motivated, are genuinely interested in their chosen topic, and are therefore quite likely to have interest in continuing the advancement of their inventions, either independently as entrepreneurs themselves or in collaboration with industrial partners."

## Kam Leong: Academia Sinica



Kam W. Leong, has been elected to the prestigious Academia Sinica of Taiwan, founded in 1928 to promote and undertake scholarly research in science, engineering and humanities. A renowned researcher in nanoscale therapeutics, Leong successfully developed nonviral gene delivery systems for hemophilia and genetic immunization.

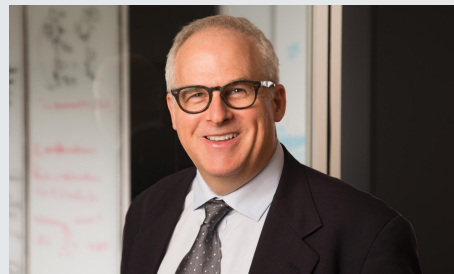
As head of the Nanotherapeutics & Stem Cell Engineering Lab, Leong and his group work at the interface of nanotherapeutics and regenerative medicine to develop new treatment strategies for inflammatory diseases and cancer.

One of his recent research directions is the development of human cell-based tissue-chips for drug development, disease modeling, and precision medicine.

“I am humbled and honored to be elected to such a distinguished body. Naturally the honor belongs to the collective effort of students, postdoctoral fellows, and collaborators over the years. There is so much more science to be done and I look forward to working with them for years to come,” said Leong.

Leong was previously elected to the National Academy of Engineering (2013) and the National Academy of Inventors (2013). He has received the Lifetime Achievement Award from the Chinese American Society of Nanotechnology & Nanomedicine, the President's Fellowship for Distinguished Scientist from the Chinese Academy of Sciences, 2015 Savio L-Y. Woo Distinguished Lectureship from the World Association for Chinese Biomedical Engineers, and the Distinguished Scientist Award from the International Journal of Nanomedicine, among many other honors.

## Andrew Laine: Erasing the Line Between Imaging and Analyzing



In the mid-1980s, Andrew Laine was a graduate student at Washington University, in St. Louis—and a whiz hacker. At the time, the three major manufacturers of medical imaging equipment used different encrypted (proprietary) codes for breast magnetic resonance imaging (MRI) scans. At his adviser's prompting, Laine cracked the codes, so the data from the various machines could be integrated and the images compared and studied.

Laine was the first to apply methods of multiscale “wavelet” representations to enhance subtle details in mammograms so they would not be missed. This not only produced better images, but also reduced the amount of radiation needed for screening. Today, the core algorithm he developed in 1992 is used in almost all commercial digital mammography systems worldwide.

Using a phased array ultrasound transducer, Laine was also the first to compute cardiac strain, which can be a precursor to a heart attack, in real time, from 4D (3D plus time) ultrasound. The 4D imaging can also detect abnormal wall motion of dead myocardial tissue resulting from a heart attack that has already occurred.

“Fostering the relationship between academia and industry,” Laine says, “is the fastest way to bring technical advances in imaging to clinical practice and improve patient care.” Laine spearheaded a partnership between Columbia and General Electric (GE) to foster translational research. It enables biomedical engineers, clinicians, and GE to jointly address unmet clinical needs that could benefit from advances in MRI technology and other imaging methods.



## Tal Danino: Engineering Bacteria to Treat Breast Cancer



In the US, approximately one in eight women will develop invasive breast cancer at some point in their lifetimes, and survival rates drop from 85 to 26 percent when the cancer becomes metastatic and spreads outside of local breast tissue regions. While chemotherapy can stall tumor growth in many cases, tumors often become resistant to treatment. And as treatment options have improved only slightly in the past 20 years, researchers like Tal Danino, assistant professor of biomedical engineering, are determined to develop new methods to treat the disease. Danino's work on programming probiotics for cancer treatment recently won him the US Department of Defense's annual Era of Hope Scholar Award, a four-year \$2.5 million grant given to young investigators doing innovative breast cancer research.

Danino's Synthetic Biological Systems Laboratory is using the rapid advances in the field of synthetic biology to engineer probiotics, computationally modeling and then constructing genetic circuits that create complex, dynamic behaviors inside of living cells. Due to the relative ease of genetically manipulating probiotics, his group can program bacteria to sense tumor environments specifically, and produce a wide variety of genetically encoded diagnostic and therapeutic agents.

"Our work is focused on transforming bacteria into 'smart' therapeutic delivery vehicles to treat breast cancer. We think that by engineering microbes that are more effective and less toxic, we can greatly improve upon the mortality associated with metastatic breast cancer," says Danino.

A member of Columbia's Data Science Institute and Herbert Irving Comprehensive Cancer Center, he studies the interaction of microbes and tumors, using DNA sequences and synthetic biology to program microbes as diagnostics and therapeutics in cancer.

Over the past decade, the human microbiome—all the genomes of the microbes in our bodies—has become a particularly fertile area for cancer researchers, who have found a widespread prevalence of beneficial microbes in the body, including those in breast tissue and human milk. They have also detected a surprising presence of microbes within breast and other tumors previously thought to be sterile. Breast cancer has been associated with imbalances in these diverse communities of breast tissue microbes.

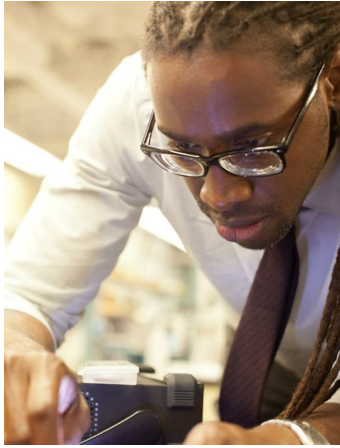
"Given their presence and selectivity for tumors, microbes represent a natural platform for development as a method to treat breast cancer," Danino says. His DoD award will support his goal to engineer orally deliverable, safe probiotics to selectively target metastatic tumor sites, and effectively produce and release a therapeutic inside the local tumor environment.

Danino envisions a major avenue of breast cancer research that will incorporate an understanding of how the microbiome shapes the development of breast malignancies, and how this microbiome could be manipulated with synthetic biology techniques. In addition, his engineered probiotics can colonize both primary tumors and metastases independent of the patient's genetic background, a function critical for difficult-to-treat breast cancer subtypes.

"Using orally administered probiotics instead of surgery or chemotherapy could transform treatment regimens," he notes.

Danino also recently received two other awards related to this work, a DoD Idea Development Award, and the 2017 Breast Cancer Research Foundation-AACR Career Development Award for Translational Breast Cancer Research.

# Aaron Kyle: Excellence in Teaching



Dr. Aaron Kyle, Senior Lecturer in the Department of Biomedical Engineering, has been named a recipient of Columbia University's Presidential Award for Outstanding Teaching after nominations from his students and colleagues. A top honor presented to only five recipients each year, the presidential awards "recognize teaching excellence at both the undergraduate and graduate levels and, in particular, honor faculty who have had a lasting influence on the intellectual development of our students."

As the instructor for the required two-semester BME Lab sequence, as well as the yearlong capstone senior design course, Kyle has proven to be an integral part of the Columbia BME undergraduate curriculum.

"Professor Kyle is a huge part of the reason why I have so much pride in being a Columbia BME," one student said. "He is the undergraduate BME experience."

Under his direction, the BME Lab sequence has grown to incorporate many aspects of the wide field of biomedical engineering, such as bioinstrumentation, biomechanics, and tissue engineering.

In the senior design course, Kyle inspires students to apply their accumulated knowledge towards solving a real-world biomedical problem. He has also created the Global Health Technology Program integrated with the senior design course in order to directly address the need for improved medical care in Uganda. The program has taken four trips to Uganda (2011, 2012, 2016, and 2017) to test device prototypes and uncover new project needs. Kyle has subsequently served as an advisor to many successful projects, some of which have matured into prominent startups.

Kyle's passion for teaching reaches beyond the undergraduate classroom. In 2014, he created the Hk Maker Lab, a program focused on introducing engineering design and STEM careers to high school students who may otherwise be underrepresented in STEM.

During the summer program, students learn about the engineering design process through a combination of interactive workshops and laboratory activities. The students then identify a biomedical problem and engineer a solution. Hk Maker Lab alumni have gone on to intern at biotechnology companies and pursue science or engineering at a number of top universities. Another element of Hk Maker Lab involves integrating engineering design into high school curriculum by training high school teachers – an effort that has been lauded by the NYC Department of Education.

Kyle's dedication to the Hk Maker Lab has not gone unrecognized. In 2016, he received a five-year, \$1.3 million NIH Science Education Partnership Award to support Hk Maker Lab's goal of educating and motivating students to pursue STEM.

Kyle joined the Columbia University Department of Biomedical Engineering as a lecturer in 2010 after completing his postdoctoral fellowship at the Indiana University School of Medicine, where he investigated the effects of electromagnetic fields on stem cells, invented a liquid metal pacemaker lead, and designed ECG analysis algorithms for ambulatory animal studies. He received his Ph.D. in Biomedical Engineering from Purdue University and a Bachelor's Degree in Electrical Engineering from Kettering University.

"I'm happy and humbled to be a recipient of the Presidential Award for Outstanding Teaching. While this is a tremendous honor, the real prize has been the opportunity to work with high schoolers via the Hk Maker Lab and BME undergraduates here at Columbia. I am proud to have had a (small) effect on these people's educational journey," Kyle says. "Also, I'd be remiss in not expressing thanks to my esteemed colleagues in BME and my family, especially my fantastic wife, Ngonidzashe, who has been unwaveringly supportive throughout all of my professional endeavors. Without her, nothing I do is possible."



## Elizabeth Hillman and Elisa Konofagou: Faculty Q&A

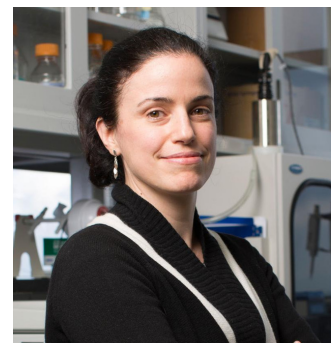
Elizabeth Hillman and Elisa Konofagou recently sat down with Dean Mary C. Boyce and a gathering of students to discuss their cutting-edge efforts to understand and heal brains.

Hillman, a professor of biomedical engineering and radiology, is director of the Laboratory for Functional Optical Imaging, as well as a principal investigator at Columbia's Mortimer B. Zuckerman Mind Brain Behavior Institute. Konofagou, also a professor of biomedical engineering and radiology, heads the Ultrasound Elasticity Imaging Laboratory.

**Q: You each engage in very cross-disciplinary collaborations with neuroscientists and clinicians. How have those interactions influenced your work?**

**Elisa Konofagou:** One reason why I work with the brain is because neurologists came to me and said “we need to have more kinds of tools available to us.” There’s a lot of desperation among clinicians because Alzheimer’s, Parkinson’s, ALS, brain tumors, you name it, are galloping ahead... Clinicians have the urgency of treating the brain and diagnosing it properly, and all these diseases are very undertreated if not untreatable right now. Neuroscientists are [more] interested in understanding the normal brain and how it works, because there’s still a lot we don’t understand about it. But this is actually the bottleneck for a lot of us—how do you actually go inside the human brain and probe it and do cool stuff without damaging it? We don’t have the tools we want right now.

**Elizabeth Hillman:** I would say one thing that interdisciplinary collaborations have forced me to do is go outside my comfort zone into new areas, where you see something and you say, “I have no idea what this is... but I am going to figure it out” Actually, I want to blow the horn of biomedical engineering here, because in BME we are these integrators of information. We have to do this to keep moving forward and discovering. If you just say, “I do imaging” and you just do imaging, that’s no good. When you have the privilege of seeing these things for the first time, it’s your responsibility to follow up.



The challenge of understanding and treating the human brain is absolutely one of the biggest things going on right now, and it really takes input from all different fields. One exciting new cross-over is neuroscience and data science. In our case, we can generate 1.5 terabytes an hour of imaging data, and we have to turn that into knowledge. We need an influx of people who understand machine learning, and deep learning models to garner meaning from the kinds of data and images that we can now get – and to ultimately to decode how the brain drives behavior.

**Q: We’ve seen tremendous progress over the last five years around research and understanding of the brain, yet we also know that we haven’t scratched the surface. Where do you think we’ll be in ten years?**

**Hillman:** Things have really accelerated. The number of research tools that are now available are incredible and at the fingertips of so many more people, including people who do disease research, which is a great transition to see... although truly ‘understanding the brain’ is going to take a long time. However, I am excited about another angle too, in which we are starting to appreciate how and why things that you wouldn’t normally call normal medicine are effective for things like depression or even brain diseases.

I think progress in the near term will be made in lot of ways, for example, I think we will find that therapy in an autistic child is actually remodeling the brain and causing it to be improved at a cellular level. We’re already learning all of this now... but I think it’s going to be incremental - I don’t think we will ever see some big announcement that “now we understand the brain,” but these little pieces will come together and start to make sense and guide us toward better diagnostics and treatments for human brain health.

# Tommy Vaughan:

## Faculty Q&A

J. Thomas (Tommy) Vaughan joined Columbia as the University-wide director of Magnetic Resonance (MR) Research, a newly created position with joint appointments at Columbia Engineering, Columbia University Medical Center, and the Mortimer B. Zuckerman Mind Brain Behavior Institute. An expert in the field of ultrahigh field magnetic resonance techniques and technologies, Vaughan is overseeing a collaborative effort to build an MR Research Center at Columbia.

### **Q. How did you get into the MRI field?**

**Vaughan:** I wanted to be an astronaut, but ended up as a civil servant for NASA on the Space Shuttle project. NASA's contractors were doing the most creative work, so I moved to Texas Instruments to work on "a government project," while going to grad school at UT Southwestern. I had studied biology and electrical engineering and, with my radar experience, it led me to an NMR course at UT. I was hired to build the first 2 tesla (2T) machine and then worked on the first 4T, 7T, 9.4T, and 10.5T MR systems, as the opportunities to work with more and more powerful magnets presented themselves.

### **Q. Columbia will be getting several state-of-the-art MR systems, some as part of a new partnership with GE. How will they be used?**

**Vaughan:** For basic neuroscience, translational R&D, and technology transfer. Columbia will be purchasing six new GE 3T MR systems and a 7T system to be located in the Neurological Institute on the Columbia University Medical Center campus. An additional 3T MR system will belong to GE, along with a complement of half a dozen GE scientists, as part of a translational research agreement between Columbia and GE. The Zuckerman Institute will have two Siemens 3T machines, one 7T system, and a 9.4T Bruker preclinical system to be used for neuroscience. These 3T and 9.4T systems will be installed in the Zuckerman Institute by the end of October 2016.



### **Q. What is the future of magnetic resonance research?**

**Vaughan:** MR will continue to be used for basic science, clinical diagnostics, and therapy tracking. One direction is using MR together with complementary modalities (CT, PET, ultrasound) to get a more complete picture. Another is toward more powerful systems using more powerful magnets that provide more signal-to-noise to give higher spatial and temporal resolution in our images. Yet another is making MRI accessible to the rest of the world.

**Vaughan:** I moved and restored a pioneer log cabin in the North Woods on the St. Croix River, on the Wisconsin side of the Minnesota–Wisconsin border. It is kind of like Lake Wobegon. The cabin dates from 1880 and belonged to a bachelor dairy farmer from the community on which Garrison Keillor's story was based. My son and I moved it to this off-the-grid location. Now that we are moving to New York, having this cabin in the Wisconsin woods will keep me connected to family and the outdoor activities I enjoy.

Another interest is cycling. When I was in college I took two years off to ride around the world, visiting 57 different countries. This was a mission to see what the world had to teach as I was trying to decide my own life's directions. I now enjoy biking the route along the Hudson, from the Morningside Heights campus, up to the Zuckerman Institute at Manhattanville, and on to the Medical Center at 168th Street and back. Cycling gives me my daily exercise, transportation, recreation, and my thought for the day.



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Biomedical Engineering & Medical Sciences  
Director, Laboratory for Stem Cells and Tissue Engineering  
Tissue engineering. Stem cells. Regenerative medicine.*



**Qi Wang**

*Associate Professor, Biomedical Engineering  
Director, Raymond and Beverly Sackler Laboratory for  
Neural Engineering and Control  
Brain-machine interfaces.*

## In Memoriam: **Christopher R. Jacobs**



Christopher Rae Jacobs, Ph.D., died July 1, 2018 at 6:30 a.m. in his home in Harlem after a long battle with cancer. Born in Buffalo, NY in 1965, Jacobs was a beloved professor of biomedical engineering at Columbia University since 2008 and a leader in the field of biomechanics, widely recognized for his seminal research in bone cellular mechanotransduction and computational biomechanics. In addition to teaching and research, he was also an author, lecturer, and avid outdoorsman who loved to golf, ski, hike and climb mountains.

The author of many papers, Jacobs recently co-authored an acclaimed text book, "Introduction to Cell Mechanics and Mechanobiology," with Hayden Huang and Ronald Y. Kwon. As director of the Cell and Molecular Biomechanics Lab at Columbia, his research aided in developing new therapies for age-related bone loss and osteoporosis. Prior to Columbia, Jacobs taught at Stanford University and at Penn State University.

Jacobs was awarded a PhD in Mechanical Engineering at Stanford University in 1994; an MS in Mechanical Engineering from Stanford in 1989, and a BS in Systems Science and Mathematics at Washington University in 1988. Among his honors, he won the prestigious Van C. Mow Medal in bioengineering and the Richard Skalak Award for best paper in the Journal of Biomechanical Engineering with Julia Chen.

Jacobs is survived by his wife, Claire M. Julian; his mother; a brother, Gregory Jacobs; and other relatives. His wife Claire gave birth to their daughter and first child, Rae Christina, on July 3, 2018.

## 2nd International Symposium on Mechanomedicine: In Memory of Christopher R. Jacobs

Columbia University's Fu Foundation School of Engineering and Applied Science invites you to the 2nd International Symposium on Mechanomedicine: In Memory of Christopher R. Jacobs, to celebrate Dr. Christopher R. Jacobs' life and contributions to engineering.

The day's event will feature 17 prominent engineers, basic scientists, and clinicians reviewing their unique approaches to detecting and treating human disease using mechanobiological approaches. Hosted by Columbia University and Columbia Engineering, and with pivotal contributions from faculty across leading domestic and international research institutions, this Symposium will develop a far-reaching community of mechanomedicine researchers, with the ultimate goal of pursuing federal support.

**October 23, 2018  
7:30 AM - 8:15 PM**

**Davis Auditorium, 4th Floor,  
CEPSR Building  
(530 West 120th Street)**

**Register at:**  
<http://research.columbia.edu/content/2018mechanomedicine>



## Endowed Professors

### **X. Edward Guo**

*Stanley Dicker Professor of Biomedical Engineering*

Endowed chairs and professorships at The Fu Foundation School of Engineering and Applied Science serve to recognize the outstanding research, teaching, and scholarship of our faculty. X. Edward Guo is a world-renowned leader in bone biomechanics and bioengineering, known for developing innovative, three-dimensional, bone imaging analysis techniques that have wide applications in osteoporosis and osteoarthritis. A pioneer in cellular and molecular bioengineering, he has developed innovative technologies to study cell responses to mechanical loading, a new field in biomedical engineering known as mechanobiology.

## Honors, Recognition, and Achievements

### **Gordana Vunjak-Novakovic**

*University Professor and Mikati Foundation Professor of Biomedical Engineering and Medical Sciences*

2018 Alan J. Hunt Memorial Lecture for 2018, University of Michigan, Ann Arbor, MI

2017-2018 Dean's Distinguished Lecture in the Basic Sciences, Columbia University Vagelos College of Physicians and Surgeons

### **Elizabeth M. C. Hillman**

*Professor of Biomedical Engineering and Radiology*

SPIE 2018 Biophotonics Technology Innovator Award

## New Professors

### **Nandan Nerurkar**

*Assistant Professor  
Biomedical Engineering*

## Election to Professional Societies

### **Barclay Morrison**

*Professor of Biomedical Engineering*

Fellow, American Institute for Medical and Biological Engineering (AIMBE)

### **X. Edward Guo**

*Stanley Dicker Professor of Biomedical Engineering*

Fellow, American Society of Mechanical Engineers (ASME)

### **Clark Hung**

*Professor of Biomedical Engineering*

Fellow, Biomedical Engineering Society (BMES)  
Fellow, International Combined Orthopaedic Research Societies (ICORS)

## Scholarly Leadership

### **Elizabeth M. C. Hillman**

*Professor of Biomedical Engineering and Radiology*

National Institutes of Health BRAIN Initiative 'BRAIN 2.0' working group of the Advisory Committee to the NIH Director

## Research Translation

### **Gordana Vunjak-Novakovic**

*University Professor and Mikati Foundation Professor of Biomedical Engineering and Medical Sciences*

Founder, Implacate (implacate-inc-msjn.squarespace.com)

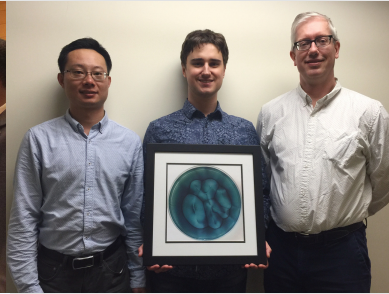
# FROM THE CLASSROOM TO THE FIELD



PhD candidate Neda Bassir Kazeruni presents a poster at the American Society of Engineering Education (ASEE) Conference



MoLabs, comprised of BME '18 Azraf Anwar, Meghana Noonavath, Jason Patterson, McKenzie Sup, and Darnell Theagene present their diagnostic device at the Senior Design Expo



Post-doc Yifei Zhang, PhD candidate Stanislav Tsitkov, and Professor Henry Hess pose with their image of an enzyme cascade, which made Nature Catalysis' April 2018 cover



Luso Labs, a cervical cancer screening startup founded by 4 BME BS'16 students won a \$200,000 prize at the 2018 Vodafone Americas Wireless Innovation Project.

## Lance Murphy BS'18: Healing Bodies, Inspiring Minds

Millions of people suffer from arthritis, one of the top causes of disability worldwide. Biomedical engineering student Lance Murphy '18 is working to change that.

Helping people heal is a lifelong passion for the South Carolina native, who grew up with nurses in the family and always intended to follow them into healthcare.

"Biomedical engineering was an easy choice," Murphy said, "I want to apply science and math to create new technologies that will change the world for the better."

For over two years he has worked in Professor Clark Hung's Cellular Engineering Laboratory on understanding how arthritis operates on a cellular level. Fulfilling a longstanding interest in joints and orthopedics, Murphy has focused much of his research on imaging the membranes from around cows' joints to observe how tissues respond to the movement of fluids. The work has important implications for engineering better replacement tissues for the knee and other joints, and he regularly consults with orthopedic surgeons on research projects.



Murphy was among just three Columbia Engineering students selected to represent the school at an international engineering conference in Chile last fall, where he presented on his research in tissue-engineered cartilage. He is currently collaborating on a senior design project developing a device to help reduce the chances that HIV-positive mothers in low-resource settings will pass on the virus to their newborns.

Outside the lab, he teamed up with friends to found the Columbia University chapter of Sci-Inspire, a club that brings student volunteers into disadvantaged schools across New York City to become mentors and help teach STEM subjects. Now in its third year, the group aims to help increase diversity and representation in STEM education and professions.



## Rachel Mintz

### BS'19:

### Intended Consequences



For biomedical engineer Rachel Mintz '19, sound science stems from curiosity, passion, and creativity. Good science requires something extra—the ability to think critically about technology's tremendous power to shape society.

The Long Island native's mission to end cancer began during high school, when she conducted research at the Feinstein Institute for Medical Research on abating kidney damage caused by the chemotherapeutic agent cisplatin. In her second semester at Columbia Engineering, she found her passion: working with a community of scholars in Professor Kam Leong's Nanotherapeutics and Stem Cell Engineering Lab to help sensitize cancer cells to chemotherapy through gene editing.

But, as Mintz quickly realized, the implications of revising DNA sequences aren't always straightforward. In particular, the technique known as CRISPR/Cas9 targets a range of genetic material with unprecedented accuracy and efficiency—meaning the same advances that enable ever more precise cancer treatments also raise profound ethical questions that once were the stuff of science fiction, such as the possibility of engineering “designer babies.” For Mintz, who routinely makes use of CRISPR/Cas9, such tools aren't to be used lightly.

“As a maturing scientist, I feel a personal responsibility not only to conduct research, but also to explore the potential social implications thereof,” she said. “Sometimes it's easy to get caught up in the nitty-gritty details of experiments, but bioethics provides a space to step back and reflect upon the larger consequences of what we're doing in the lab.”

Seeking out peers and professors across the university to engage in these complex discussions has enriched her work in numerous ways, such as a collaboration with bioethics experts John Loike and Ruth Fischbach that resulted in her helping edit the updated edition of *Science-Based Bioethics: A Scientific Approach to Bioethical Decision Making*.

Currently, she's also writing her own paper on the ethics of germline editing in context of philosophical autonomy frameworks from Immanuel Kant and Joel Feinberg.

Outside the lab, Mintz looks for other opportunities to channel her interests into positive impact.

An Eggleston scholar, she serves as president and cofounder of the student-run Systems Biology Initiative, which works to enhance knowledge of synthetic biology on campus and beyond, curating a YouTube channel, and offering workshops for New York-area high school students. The initiative grew out of her team in the International Genetically Engineered Machine (iGEM) Competition, who earned a gold medal for programming skin microbes to secrete natural mosquito repellent. “I have always loved solving puzzles,” she said, “which translated into my passion for engineering.”

Mintz also serves as co-president of Columbians Against Cancer, which works with the American Cancer Society (ACS) to organize the annual Relay for Life fundraiser on campus. The group raises some \$40,000 a year for cancer research, treatment, and education, and volunteers at the ACS Hope Lodge in midtown Manhattan. Further afield, she traveled to Rio de Janeiro in 2016 as part of a Columbia Engineering design challenge for which she helped develop a novel system for sustainable air conditioning.

This spring, Mintz received a prestigious Goldwater Scholarship, which recognizes some of the nation's most promising undergraduates in engineering, mathematics, and the natural sciences. She was also selected to address the incoming Class of '22 at the annual Academic Assembly this August. Looking ahead, she plans to pursue both an MD and a PhD and hopes to one day direct her own lab engineering cutting-edge treatments for cancers while treating patients as a physician-scientist.

“Growing up, I knew many people who battled cancer or unfortunately passed away,” Mintz said. “Biomedical engineering is especially rewarding because it combines multiple disciplines, such as electrical engineering, computer science, and mechanical engineering, with biology to formulate realizable medical solutions.”

## Nicole Moskowitz

### BS'14, MS'15:

### Forbes 30 under 30

Biomedical engineer Nicole Moskowitz '14 MS '15 recently made Forbes' annual list of 30 Under 30 shaping the future of healthcare. She is co-founder and chief technology officer of IntuiTap Medical, a startup developing a handheld device designed to eliminate the guesswork from spinal punctures. Nearly 13 million times per year in the United States alone, physicians must access the spinal canal for epidural steroid injections in pain management, lumbar punctures, or spinal and epidural anesthesia in obstetrics or orthopedic surgery. Conventional techniques often require multiple attempts to properly place the needle, which can be both time-consuming and painful. Now, nearly half of the cases seen in emergency rooms are sent to radiology departments for needles to be inserted under X-ray guidance, which exposes patients to radiation and increases the cost of care.

IntuiTap's innovative handheld device offers low-cost imaging for detection of the underlying vertebrae, needle guidance for reliable needle positioning and insertion, and digital pressure-sensing. Using tactile sensing, essentially a form of computerized palpation, to visualize patients' underlying bony landmarks, the device helps physicians access the spinal canal on the first attempt.

"I'd always wanted to channel my passions for math, physics, and art into solutions for the healthcare space," says Moskowitz, who focused on biomechanics, neural engineering, and brain-computer interfaces during her years at Columbia Engineering. "What Columbia so emphatically demonstrated, and what I see now every day, is that medical device development is inherently reliant on cross-disciplinary insights and skills."



Among her most influential mentors at Columbia Engineering were Senior Lecturer in Biomedical Engineering Aaron Kyle, who got Moskowitz interested in medical devices, and Professors Paul Sajda, Qi Wang, and Nima Mesgarani, with whom she worked on direct neural interfaces.

Since incorporating last year, IntuiTap has started a round of seed funding, taken part in the TMCx and MedTech Innovator accelerator programs, been awarded space at Johnson & Johnson Innovation's JLABS at Texas Medical Center, and become a member company at Chicago's Insight Accelerator Labs and MATTER healthcare incubator.

Moskowitz currently works in Chicago overseeing the team's research and development activities and product development partnership with the design innovation consultancy Insight Product Development. Suiting her wide-ranging interests, she has also taken the lead on establishing a Midwest clinical network and developing the company's regulatory and reimbursement approach.

"It's incredibly exciting to be involved in a venture from discovery of an unmet need through the development process and into a full-fledged entrepreneurial endeavor," Moskowitz said. "The process has been a terrific learning experience—in networking and integrating across disciplines and skill sets, in cultivating leadership qualities, and in comprehending and managing every aspect of a technology's lifecycle."





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